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Technical Memorandum

TESTING THE F-18 AT THE U.S. NAVAL AIR TEST CENTER

Mr. J. L. Dunn

F-18 Lead Engineer
Naval Air Test Center

Prepared for

1978 Society of Flight Test Engineers Symposium

14 August 1978

NAVAL AIR TEST CENTER
PATUXENT RIVER, MARYLAND

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The U.S. Navy is procuring the F-18 as a replacement for the F-4 and A-7 aircraft starting in 1983. The F-18 design advancements include control-by-wire digital flight control system, cockpit designed for one man operability, state-of-the-art avionics integration by software/multiplex techniques, and a high use of composite materials. The unique aspect of the F-18 Full Scale Development program is that it will be principal sited at the Naval Air Test Center, Patuxent River, Maryland.

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PREFACE

This paper is the result of work being accomplished by the U.S. Naval Air Test Center in preparation for the F-18 Full Scale Development program.

The paper was prepared for presentation to the 1978 Society of Flight Test Engineers Symposium to be held in Arlington, Texas, on 4-6 October 1978.

J. L. Dunn

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F-18 Lead Engineer
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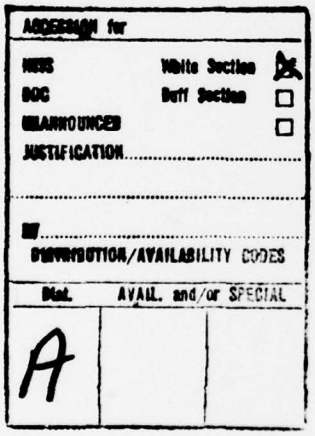

APPROVED FOR RELEASE

J. H. Foxgrover

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Commander
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TESTING THE F-18 AT THE U.S. NAVAL AIR TEST CENTER

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ABSTRACT

The U.S. Navy is procuring the F-18 as a replacement for the F-4 and A-7 aircraft starting in 1983. The F-18 evolved from the YF-17 prototype which was a part of the U.S. Air Force Light Weight Fighter Competition in 1974. F-18 design advancements include control-by-wire digital flight control system, cockpit designed for one man operability, state-of-the-art avionics integration by software/multiplex techniques, and a high use of composite materials.

From the Navy viewpoint, the unique aspect of the F-18 Full Scale Development (FSD) program is that it will be principal sited at the Naval Air Test Center (NAVAIRTESTCEN), Patuxent River, Maryland. Present plans for the FSD program are based on 11 test aircraft and 3100 test flights with first flight scheduled for late September 1978. NAVAIRTESTCEN involvement to date has consisted of participation in the design review process, Navy Integrated Test and Evaluation Working Group, Aircrew Systems Advisory Panel, and participation in simulation evaluations in St. Louis. The on-site preparation phase has consisted of establishing a management plan, ensuring that adequate facilities, support aircraft, airspace, and data and instrumentation systems are available.

INTRODUCTION

In 1972, the Chief of Naval Operations initiated a study to determine how to best maintain Naval Air Superiority in the 1980's. This study resulted in the VFAX Concept for the U.S. Navy. Under this concept, it was decided to build a lightweight, highly maneuverable aircraft that would eventually replace the F-4 and A-7 in the fighter and light attack roles. The concept called for the aircraft to be designed to a cost low enough such that the aircraft could be procured in large quantities in order to maintain an adequate tactical air deterrent within the U.S. Navy. By 1974, the Naval Air Systems Command (NAVAIRSYSCOM) had received and was evaluating five different design proposals from the aerospace industry for a VFAX aircraft. At this point, the Navy was directed to use to the maximum extent the hardware and technology in the U.S. Air Force air combat fighter competition in the next generation Navy fighter. The Navy reviewed both Air Force test data and proposals by LTV-General Dynamics for a carrier suitable version of the YF-16 and by McDonnell Douglas-Northrop for a carrier suitable version of the YF-17. In April 1975, the Navy selected a version of the YF-17, later to be known as the F-18, as the winner of the competition, primarily because it was more suitable for modification to the Navy mission and shipboard environment. In January 1976, NAVAIRSYSCOM signed a formal contract with McDonnell Aircraft Company to build the F-18. The contract included 11 FSD aircraft and options for the first 219 of 800 planned production aircraft. The innovative aspect of this contract from the test and evaluation viewpoint was that the FSD program was directed by NAVAIRSYSCOM to be principal sited at the NAVAIRTESTCEN, Patuxent River, Maryland.

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AIRCRAFT DESCRIPTION

Although the F-18 retains the basic aerodynamic shape of the YF-17, significant changes have been incorporated to make the aircraft carrier suitable in addition to those necessary to meet Navy mission requirements. The major changes from the YF-17 to the F-18 are shown in figure 1. F-18 carrier suitability was obtained by adding 12 percent more wing area, catapult and arresting gear capability, redesign of the landing gears, and strengthening of the fuselage to take carrier loads. The Navy mission requirement included an all-weather fighter capability necessitating the addition of the Sparrow missile and all-weather avionics. Range and performance needs dictated the addition of over 4000 lbs. of internal fuel and an increase in engine thrust.

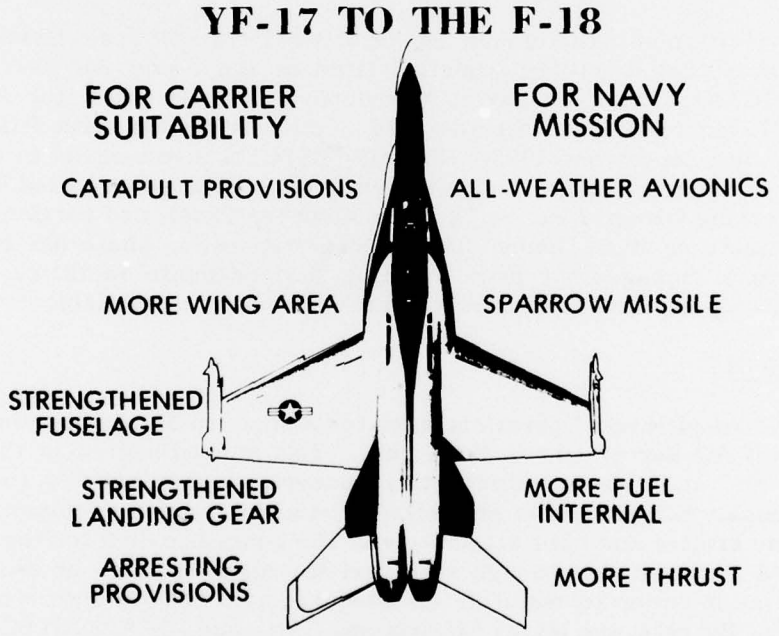


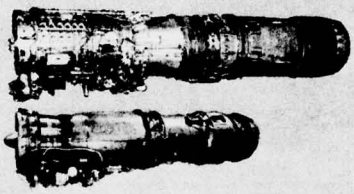
Figure 1
Changes from the YF-17 to the F-18

The F-18 can best be described as single place, twin tail, twin engine high performance fighter/attack aircraft for the U.S. Navy and Marine Corps. Its size falls between the A-7 and F-4. Three F-18's take the same deck space as one F-4 and two A-7's, approximately the ratio of aircraft it will replace aboard ship.

The General Electric F404-GE-400 is a direct derivative of the YJ101 used in the YF-17 prototype program. The engine was thoroughly tested during this program throughout the YF-17 envelope at extreme corners and attitudes. These attitudes included up to 63° angle-of-attack and a 43° angle-of-attack combined with over 35° yaw. The engine/airframe configuration of the F-18 is still basically the same as the YF-17. The changes from the YJ101 to the F404 include increasing the bypass ratio from 0.2 to 0.34, a 50°C increase in turbine inlet temperature and approximately a 1-in. increase in radius in the afterburner area. A comparison between the F404 and the J79 is shown in table I:

Table I
Comparison between the F404 and J79 Engine

Engine	F404	J79
Length	158.8 In.	208 In.
Weight	2115 Lb.	3845 Lb.
Parts	14,300	22,000
Thrust Class	16,000 Lb.	18,000 Lb.
Thrust to Weight	8 to 1	5 to 1



The avionics system is designed for one-man operation providing him with the necessary controls and displays and the means of using his weaponry to the fullest extent. Reducing pilot workload to allow efficient one-man operation dictated integration and concentration of displays and controls up front within easy reach and vision. By use of the current state-of-the-art multiplex techniques, complete fighter and attack capability is provided in a smaller size cockpit than in present fleet aircraft. The primary flight instrument is the head-up display. Two Cathode Ray Tubes (CRT's), one on the right and one on the left, as shown in figure 2, provide a synthetic radar scope and a multimode display for control of armament, moding, built-in-test (BIT), and display of Electro-Optics (EO) weapon sensors. The synthetic radar display provides an uncluttered view of radar information with a memory so that it does not have to be watched constantly. These CRT's are identical, offering display interchangeability. An up-front control in the middle allows all communication and identification to be selected and controlled within easy reach of either hand. An electronic horizontal situation display is located below the up-front control.

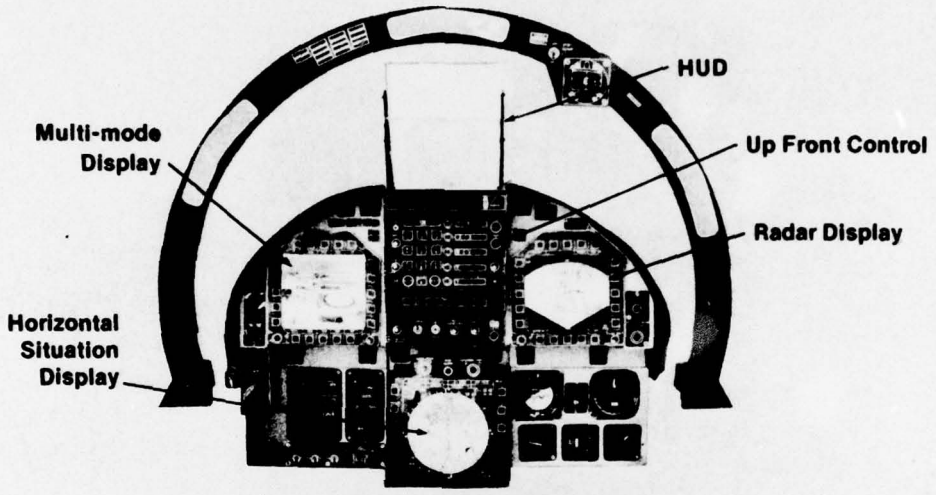


Figure 2
Controls and Displays

The Airborne Weapon Control System is made up of a multimode radar, Forward Looking Infrared (FLIR), and Laser Spot Tracker (LST). The radar provides numerous modes for detecting and acquiring airborne targets and guides the Sparrow missile to the target. The FLIR and LST give additional aid for detecting and attacking ground targets with guided and unguided weapons.

The armament is carried on nine store stations for a total capability of nearly 14,000 pounds as shown in figure 3. The primary air-to-air armament is carried on four dedicated stations. Sidewinder close-in missiles are on each wing tip for low drag and optimum sensor look angle. Medium range Sparrows are carried on each of the lower "corners" of the fuselage. An additional Sparrow or Sidewinder can be carried on each outboard wing station. An M61, 20mm cannon is mounted in the fuselage ahead of the cockpit.

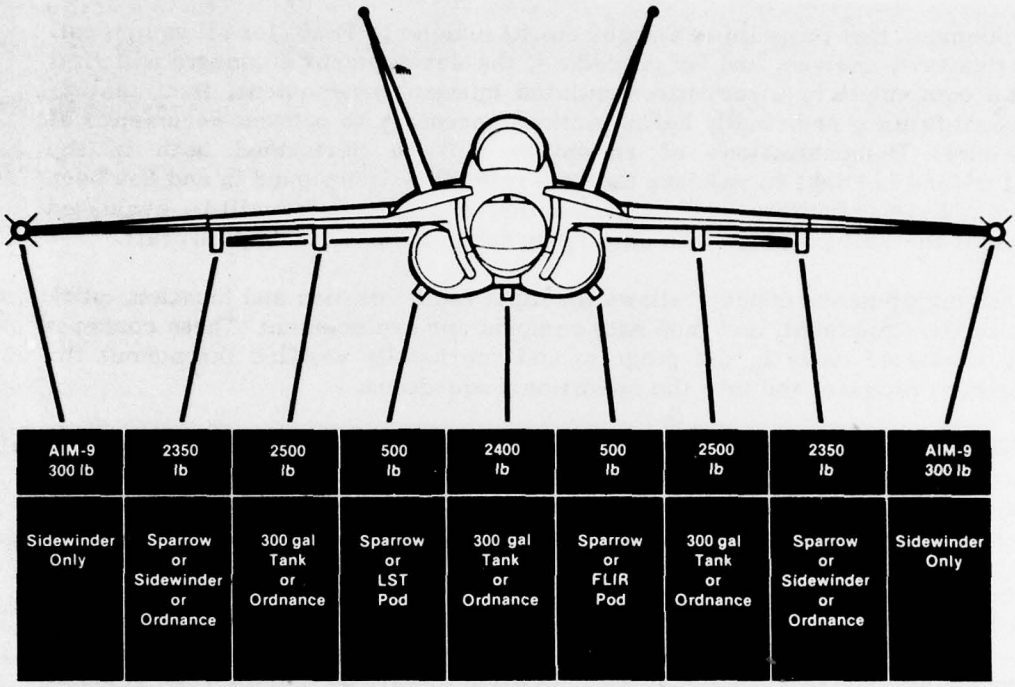


Figure 3
F-18 Armament Capability

The inboard wing stations and centerline station carry three 300 gallon external fuel tanks or a full range of conventional or guided air-to-ground weapons. The outboard stations are used for ordnance. All the wing pylons are interchangeable. The weapons are carried on Vertical Ejection Racks (VER's) for straight down ejection.

For the attack version, the FLIR and LST pods replace the Sparrows on the fuselage corners. These two pods are used in the air-to-ground mission to enhance weapons delivery accuracy.

The key factor in the success of the F-18 will be the attainment of reliability much higher than current aircraft. This reliability improvement is being accomplished by a front-end loaded program with several critical steps. The first key step is designing into each piece of equipment the specific reliability needed to meet the overall requirement. MCAIR has established reliability experts as an integral part of the F-18 team to aid the designers, to track how they are doing, and to review the designs to insure that the needed reliability has been designed in.

Both Navy and MCAIR Management are placing heavy emphasis on reliability by design with easy maintenance built into the system. The design reviews have treated reliability as an equal to performance, cost, etc. These stringent requirements were written into all procurement specifications for subcontracted equipment.

A development test program is a requirement (unique to F-18) for all equipment. Under this test, analyze, and fix procedure, the development engineers will first test the equipment in a realistic simulated mission environment, then analyze any and all failures and finally define actions necessary to prevent recurrence of the failure. Demonstrations of reliability will be performed both in the laboratory and in flight to validate that the reliability is designed in and has been attained. F-18 reliability and maintainability characteristics will be evaluated throughout the FSD program with data being taken from all 11 test aircraft.

The F-18 maintenance concept allows for rapid fault isolation and location, quick access to the equipment, and then easy removal and replacement. These concepts will be evaluated early in the program and continually verified throughout the development program and into the operational squadrons.

The BIT capability in the F-18 covers 98 percent of the contractor furnished avionics and many of the consumables. A caution light warns the pilot of a failure and the pilot can then call up on the multimode display a BIT monitor which indictes what has failed. On the ground, the ground crew checks the BIT status panel in the nose wheel well giving a more detailed indication of the fault and what door it is behind. Each piece of equipment has a failure flag confirming that it has failed.

A consumables panel gives a go, no-go indication of various liquid levels including engine oil, hydraulic fluid, radar coolant, sidewinder nitrogen, and APU oil. This allows a quick check of a panel prior to flight rather than opening numerous doors to check gages.

Major emphasis was put on designing the F-18 for excellent carrier suitability. This action includes catapult, approach, and arrestment performance as well as handling on the decks of the carrier.

The F-18 has the capability of carrying heavy payloads from the carrier with no or very little wind-over-deck. Even with heavy loads, only a few knots of carrier speed are required. As a comparison, the F-4J, even with no payload, requires some wind-over-deck.

The redesign of the wing, leading edge extension, and flap system allows the F-18 to make a slow flat approach to the carrier. At the minimum approach speed, the angle-of-attack of the aircraft is less than 9^{o}. With the 13^{o} over-the-nose visibility, the pilot is offered an excellent view of the carrier.

The excellent reliability and maintainability keeping the aircraft "full systems ready" will contribute greatly to the low deck handling requirements. The self-start and checkout of systems with the onboard APU will reduce the support equipment required. The servicing areas are so arranged that maintenance personnel can conveniently "turn the aircraft around" without interfering with each other.

SCOPE OF TEST PROGRAM

The F-18 FSD program will consist of 11 test aircraft as shown in figure 4. The 11 test aircraft will fly approximately 3100 flights (273 aircraft test months) over a 3 1/2 year period. Nine of the FSD aircraft will be single-seaters with aircraft numbers 7 and 10 being the two-seater trainer version of the F-18.

Approximately 8 percent of the F-18 aircraft to enter fleet usage will be in the two-seat (TF-18) configuration. The first nine FSD aircraft will be fully instrumented with on-board magnetic tape recording and telemetry systems. All flying will be conducted at NAVAIRTESTCEN with the exception of the initial checkout flights which will be flown at the MCAIR facility in St. Louis. An additional element in the test program is a T-39 radar test bed aircraft. This aircraft is presently being flown from the Hughes, Culver City, California, facility. By using the T-39, the radar test program has been able to get a significant headstart from the development, test, and evaluation viewpoint.

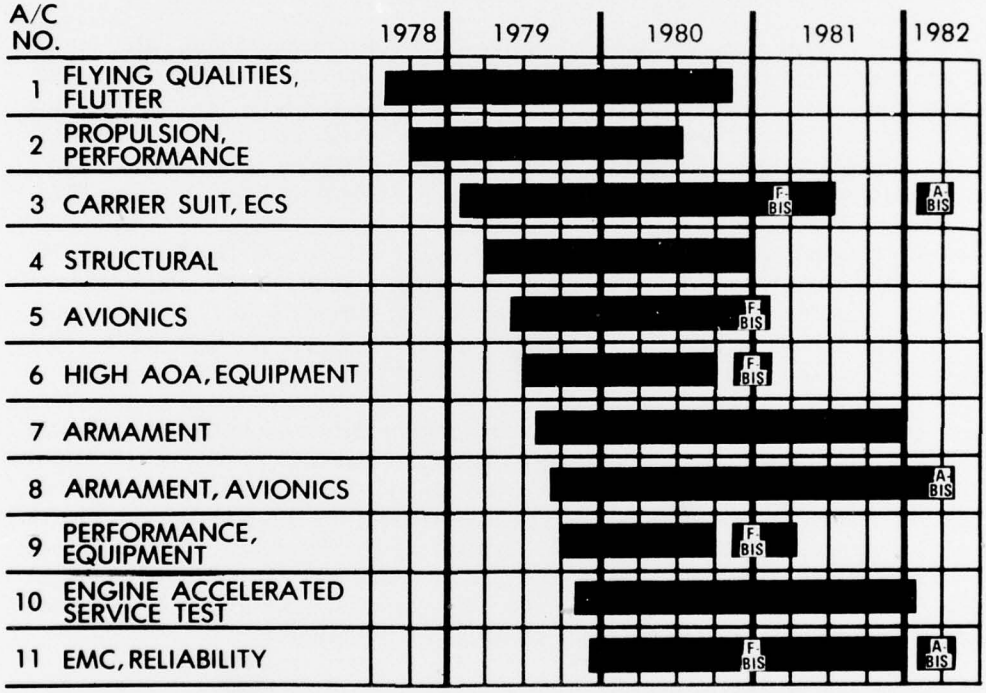


Figure 4
F-18 Flight Test Schedule

The overall F-18 FSD program utilized the Test, Analyze, And Fix (TAAF) philosophy with a logical progression of testing from the smallest element to full scale demonstration per MIL-D-8708B(AS). The F-18 is based on a foundation of technical and operational experience from the YF-17. The two YF-17 aircraft have flown over 300 flights. Because of this foundation, the F-18 FSD program represents a significant reduction in risk from that normally associated with a new aircraft development program.

TESTING STATUS

F-18 testing to date has included wind tunnel models, simulations, structural test articles, components, subsystems, and system test articles, test engines, and the T-39 flying radar test bed. The wind tunnel test program has been used to verify and refine the analytical aerodynamic, flutter, loads, and propulsion studies. Over 9,000 wind tunnel hours have been utilized to date. Of this amount,

approximately 5,000 hours have been spent evaluating low and high-speed performance and stability characteristics, stores effects and separation, high angle-of-attack/spin characteristics, powered approach configuration, and ground effects.

Manned flight simulation tests have utilized over 3,500 hours to provide decision-making data for configuration features. These tests were conducted in both the MCAIR Manned Air Combat Simulator (fixed base/360° visual simulation) and in the MCAIR 6 degree-of-freedom motion base simulator. The Manned Air Combat Simulator has been used extensively to optimize the layout and configuration of the cockpit design.

In the avionics area, acceptance testing has commenced on all major components. Software design, FORTRAN validation, operational flight program coding, and checkout have been completed for the first airplane. The T-39 radar test bed flew its first flight on 1 February 1978 and since that time has completed approximately 25 radar development flights. The first Navy Preliminary Assessment of the F-18 Radar System is scheduled for October 1978.

Full scale development of the F404-GE-400 engine started in November 1975. Eleven new F404 development engines and two refurbished YJ101 engines have been used to accumulate over 6,000 hours of test time. A major milestone, Preliminary Flight Rating Tests (PFRT), was completed during June 1978. This was a major goal in achieving readiness for first flight.

As a part of the flight control system verification process, both MCAIR and NAVAIRTESTCEN pilots will conduct an in-flight evaluation of the F-18 flight control laws prior to F-18 first flight using the CALSPAN variable stability NT-33 aircraft. This approach has been used previously on the YF-16 and YF-17 flight test programs. Approximately 20 flights were flown on the NT-33 at NAVAIRTESTCEN in the July 1978 time frame. The results of the in-flight simulation will be used to complement the ground simulator evaluations previously conducted by MCAIR at their facility in St. Louis.

PRINCIPAL SITE CONCEPT

From the Navy viewpoint, one of the most unique aspects of the F-18 FSD program is that in 1975 the NAVAIRSYSCOM decided to principal-site the test program at NAVAIRTESTCEN, Patuxent River, Maryland. The principal-site concept will allow for a more efficient cross utilization of the 11 FSD test aircraft, will permit Navy test personnel to become more knowledgeable about the development aircraft earlier in the development cycle, and will require only one logistics pipeline for the development program. Previous Navy FSD programs of this magnitude utilized both contractor and various Navy test facilities concurrently to accomplish the goals of the particular test program.

Principal site testing promotes test efficiency through joint utilization of test data and through elimination of redundant testing. As an example in previous programs, the contractor would conduct buildup end points at his test facility and then repeat those points during the formal demonstration at the NAVAIRTEST-CEN. For the F-18 program, it is planned to formally accept the contractor's buildup end points since Navy engineers will be closely monitoring the results of the flight test program. This approach is expected to result in significant cost savings both in terms of dollars and flight hours.

It should be pointed out that, although the contractor will be conducting his flight test program at the NAVAIRTESTCEN, the Navy will not direct the contractor's effort. Under the terms of the contract, MCAIR has the responsibility for developing the F-18 aircraft. The Navy will conduct formal Navy Preliminary Evaluations (NPE's) at approximately 6-month intervals to assess the overall progress of the F-18 development cycle as is the case with a more traditional program. However, by having monitored the contractor's program closely, the NAVAIRTESTCEN will be able to make more intelligent and efficient use of the dedicated Navy flight time during the NPE process.

NAVAIRTESTCEN PREPARATION

Since April 1975, the NAVAIRTESTCEN has been working closely with MCAIR to identify required facilities and support services for the F-18 FSD program. The first step in this procedure was the accomplishment of a site survey by MCAIR as a first attempt to match existing facilities and support services to those required to support the F-18 FSD program. The next step was the publication by MCAIR of a formal facilities requirements document specifying to the Navy all support required for the F-18 program. Based on these requirements, NAVAIRTESTCEN commenced a limited facilities modification program to ensure that all the necessary facilities would be in the proper configuration and operation by the time the F-18 arrived at Patuxent River. Some of the major items considered in this preparation phase included the following:

a. Hangar facilities modification.

b. Procurement and installation of additional two streams of Real-Time Telemetry Processing System (RTPS) capability.

c. Chase/Target/Tanker support aircraft.

d. Air-to-Air and Air-to-Ground target support capability.

e. Data support for MCAIR.

f. Airspace Requirements.

g. Secure data communications link between NAVAIRTESTCEN and MCAIR, St. Louis.

h. Arresting gear installation at Wallops Flight Center (WFC) (primary divert field).

i. Bomb and missile buildup/support.

j. NAVPRO function at NAVAIRTESTCEN.

In addition to the physical preparation, much attention has been given to setting up a NAVAIRTESTCEN F-18 Management Team. Using the NAVAIRSYSCOM Program Manager concept as a model, the Director of the Strike Aircraft Test Directorate established the F-18 Program Office to centrally manage both the preparation for and actual conduct of the Navy portion of the F-18 program at Patuxent River. The Program Office is comprised of six officers and two engineers. This central cadre, in turn, teams up, in a matrix fashion, with the

project personnel located in the various test center directorates and branches. At the present time, there are approximately 150 NAVAIRTESTCEN technical personnel working on the F-18 program anywhere from 5 to 95 percent of their time. This system of management is proving to work very effectively in accomplishing the assigned tasks.

NAVAIRTESTCEN INTERFACES

Because of the size and scope of the F-18 FSD program, it has been necessary to coordinate a number of external interfaces to ensure that all aspects of the program receive proper consideration. Figure 5 shows the activities that NAVAIRTESTCEN is working with to ensure adequate support and implementation of the test program. In past programs, these relationships were informal or did not exist at all.

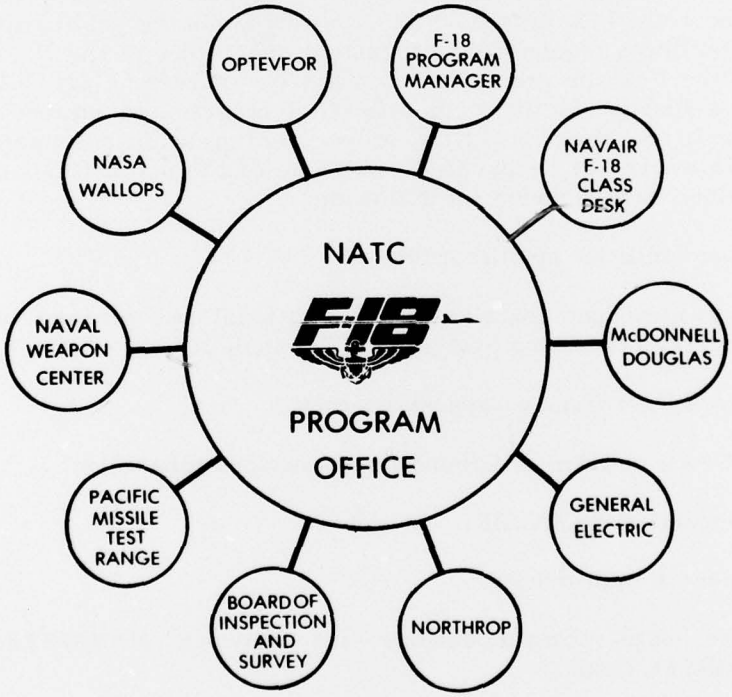


Figure 5
NAVAIRTESTCEN F-18 Relationships

For the F-18 program, NAVAIRTESTCEN has established in writing through a series of memoranda of agreement (MOA) what our relationships are with five of the participating activities. Essentially, these MOA's spell out the various relationships necessary to accomplish FSD testing in a smooth and efficient manner. For example, the MOA with WFC establishes the relationship required to utilize the off-shore warning areas 108/386. Likewise, the MOA spells out what level of support WFC will provide in terms of people and equipment and how they will be reimbursed financially by the Navy for these services.

The MOA with MCAIR spells out to what extent the Navy may be present during MCAIR briefings and debriefs and to what level the Navy has access to contractor data during the development phase of the program. The MOA with General Electric is very similar to that of the MCAIR MOA. These MOA's serve to spell out in detail how the parties have elected to interface with each other. They also provide a means of continuity in procedures for personnel rotating into the test program. It is recognized that the MOA's are not an end in themselves, but that it is up to individuals within the test program to ensure that the day-to-day test operations run as smoothly as possible.

TEST PREPARATION

Final test preparation at NAVAIRTESTCEN has been concentrated on two areas. Number one is to ensure that all facilities and support services are ready and have been checked out. As of the present time, all facility modifications for the F-18 have been completed and are in the final stages of test. All support services, such as telemetry equipment and data processing programs, are on-line and operational. Support aircraft have been identified and are ready. The second major item has been to ensure that all members of the Navy Test Team know what is expected of them and that they have a detailed understanding of the portion of the F-18 for which they have test cognizance. This step has been accomplished by participating in contractor systems design reviews, participating in simulator evaluations at the MCAIR facilities in St. Louis, and by attending formal training courses prepared by MCAIR prior to start of the actual flight test program. The Navy engineers are also establishing data requirements to use as a checklist in preparing for the formal NPE's, the first of which is scheduled for January 1979.

Significant attention is being given to understanding the software used in the F-18 by using the Mission Systems Test Laboratory (MSTL) presently under development at the NAVAIRTESTCEN. The MSTL is a software test facility that can be utilized to test the F-18 Operational Flight Program (OFP) under highly controlled conditions prior to actually conducting flight test in the F-18.

The MSTL will also be utilized to duplicate in-flight anomalies detected during FSD. This action will be achieved by playing back the actual airborne data tape through the MSTL and then going through a fault isolation procedure. As discussed earlier, the T-39 radar test-bed program and the CALSPAN NT-33 control law verification program will provide the Navy with a headstart in the evaluation of these two areas.

CONCLUSION

The NAVAIRTESTCEN has completed principal-site facilities preparation for the F-18 program. All support services and equipment have completed necessary checkout procedures. Testing of the F-18 components is continuing in an orderly manner with NAVAIRTESTCEN personnel gaining the experience and expertise necessary to conduct the NPE's in an intelligent and efficient manner. The NAVAIRTESTCEN will support the contractor to the maximum extent possible while at the same time allowing him adequate latitude in developing the F-18 for the U.S. Navy.

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